PATENT ABSTRACTS OF JAPAN

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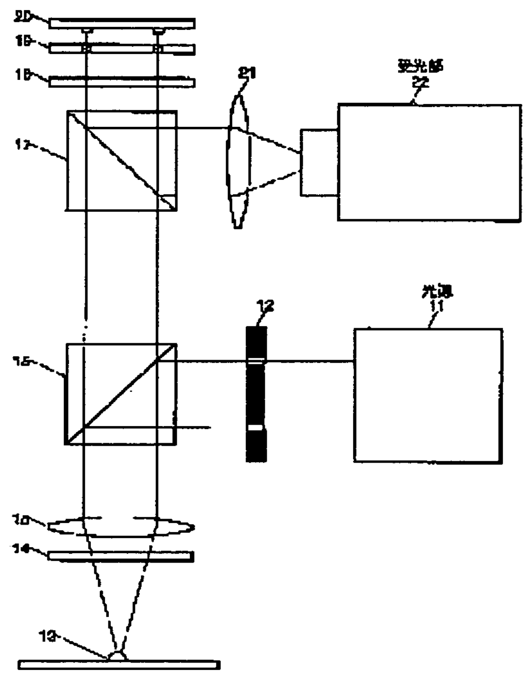
(54) THREE-DIMENSIONAL SHAPE MEASURING INSTRUMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To measure the three-dimensional shape of a body to be measured over a relatively wide range in a short time without contacting.

SOLUTION: The direct reflected light (0th-order light) of the reflected light generated when the body to be measured is irradiated with light is guided by a discriminating optical system to a variable-phase filter and the high-order diffracted light is guided to a fixed reflection part; and they are reflected respectively and converted by an interference optical system on nearly one point to interfere with each other. In this state, a movable reflection part of the variable-phase filter is moved within the range of the wavelength of light in use and then the phase of the 0th-order light which is reflected there gradually shifts from the phase of the high-order diffracted light which is reflected by the fixed reflection part, so that the interference light of both the lights at the image formation point of the interference optical system gradually varies in intensity. The position of the movable reflection part of the variable-phase filter at the maximum intensity point of the interference light depends upon the distance between the starting point (reflection point) of the body to be measured and the movable reflection part, so the position of the starting point can be calculated from the position.



LEGAL STATUS

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CLAIMS

[Claim(s)]
[Claim 1] a) The phase adjustable filter equipped with the radar clutter section and the movable reflective section movable in the direction of an optical axis, b) Judgment optical system which leads the zero-order light emitted from each point of a device under test to the above-mentioned movable reflective section or the radar clutter section, and leads the high order diffracted light to the above-mentioned radar clutter section or the movable reflective section, respectively, c) The interference optical system which makes the high order diffracted light by which reflection was carried out [above-mentioned] with the zero-order light by which reflection was carried out [above-mentioned] lead and interfere in an abbreviation same point, d) Solid configuration measuring device characterized by having the light sensing portion which measures the reinforcement of the above-mentioned interference light, and the spotting section which determines the location of the direction of an optical axis of each point of a device under test based on a change of the above-mentioned interference light measured by the light sensing portion on the strength, moving the e movable reflective section in the above-mentioned optical-axis direction.
[Claim 2] The solid configuration measuring device according to claim 1 characterized by preparing an extinction filter ahead of the part which reflects the zero-order light of a phase adjustable filter.
[Claim 3] The solid configuration measuring device according to claim 1 or 2 characterized by having made cyclic light projected on a device under test, and making the movable reflective section cyclic [corresponding to it] in a phase adjustable filter.
[Claim 4] The reflective type according to claim 1 to 3 characterized by making the incident light study system which projects light from the light source to a device under test by arranging the light source and the above-mentioned judgment optical system to the same side about a device under test, and using polarization, and the above-mentioned judgment optical system live together of solid configuration measuring device.
[Claim 5] The transparency type according to claim 1 to 3 characterized by having arranged the light source and the above-mentioned judgment optical system to the opposite side about a device under test of solid configuration measuring device.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the solid configuration measurement technique according the detailed solid configuration of nano meter order to the optical probe method a high speed and for measuring easily.
[0002]
[Description of the Prior Art] In order that the silicon society which is a basic industry for supporting the more and more development of the IT industry may oppose many foreign countries, such as the U.S., development of a next-generation semi-conductor can be called important project which lifts a state. The success or failure of this next-generation semi-conductor development are left to manufacture of the hyperfine structure of nano meter order (wiring width of face of 0.1 microns or less), and establishment of an inspection process technique.
[0003] Moreover, the multilayer-interconnection technique of wiring in three dimensions is indispensable as an improvement technique in a degree of integration in recent years. Therefore, establishment of the solid configuration measuring method of nano meter order is indispensable.
[0004] A concrete example is given. in order to raise the degree of integration of a semiconductor device -- a circuit pattern -- thinning -- it has multilayered. For this reason, the pattern level difference formed on a wafer will need to be formed into a low level difference using flattening techniques, such as CMP (Chemical Mechanical Polishing, chemical mechanical polish). In order to set up the process conditions of CMP appropriately, it is necessary to measure how many level differences were beforehand removed for every various conditions, and to correct an abrasive material, polish time amount, etc. according to it. Moreover, also in daily management, a level difference removal condition must be supervised and fault must be coped with by discovering at an early stage. Also for the reason, the approach of measuring the level difference of nano meter order simple quickly becomes indispensable.
[0005] When it divides roughly, there are the following two methods in the approach of evaluating the fine structure of the conventional nano meter order.
[0006] 1) It is the mechanical probe scanning mode represented by the machine probe method atomic force microscope (AFM:Atomic Force Microscope). Although a machine probe method can measure the configuration of a three dimension with high precision, since it is what (a probe and a device under test are moved relatively) scans a probe two-dimensional mechanically, there is a fault that a scanning zone (= measuring range) is narrow. Moreover, since it is a mechanical scan, a scan speed is slow, and high-speed measurement cannot be performed.
[0007] 2) It is a method using interference of an optical probe method light, and is represented by the differential interferometer. Although it has the features that high-speed measurement is possible for an optical probe method, there is a fault that distinction of concave or a convex being impossible and the detailed survey of the amount of irregularity are difficult.
[0008]
[Problem(s) to be Solved by the Invention] This invention is accomplished paying attention to the

approach using the phase contrast information resulting from the optical path difference produced with irregularity.
[0009] As an approach using phase contrast information, the phase-contrast microscope is known conventionally. A phase-contrast microscope actualizes the optical-path-length difference of the light produced according to the delicate component difference inside a living thing cell, is the technique of making it the image which can be viewed, and is used for observation of the structure inside a cell useful.
[0010] However, although concavo-convex recognition can be performed in a phase-contrast microscope, measurement of the amount of irregularity (the amount of phase contrast) is impossible. Since the phase filter used since phase contrast is produced is created with glass, this originates in phase contrast always being fixed.
[0011] In order to acquire high contrast or to secure sufficient quantity of light, there is an example which devised the phase plate in the conventional technique about a phase-contrast microscope, but in order to measure a solid configuration, there are not a phase plate which can set a phase as arbitration, and an example incorporating it.
[0012] For example, in JP,9-80313,A "a phase-contrast microscope, the light absorption object used for it, and a phase plate", the phase plate with which absorption coefficients differ according to the amount of phase contrast of a measuring object object till then is prepared, and the phase plate for what was being exchanged according to the sample changing an absorption coefficient continuously, and raising contrast is offered. However, it is not for measuring a solid configuration.
[0013] Moreover, the equipment currently indicated by JP,2000-10013,A "a phase-contrast microscope and a superposition measuring device" has the advantage of observing an image with it, by securing sufficient quantity of light while obtaining a low level difference wafer alignment mark by high contrast. [low therefore extent influenced of the aberration of image formation optical system for the purpose of shortening the measuring time, and] [exact] However, it is not a thing for this to measure a solid configuration, either.
[0014]
[Means for Solving the Problem] The phase adjustable filter with which the solid configuration measuring device concerning this invention was equipped with a radar clutter section and the movable reflective section movable in the direction of an optical axis, b) Judgment optical system which leads the zero-order light emitted from each point of a device under test to the above-mentioned movable reflective section or the radar clutter section, and leads the high order diffracted light to the above-mentioned radar clutter section or the movable reflective section, respectively, c) The interference optical system which makes the high order diffracted light by which reflection was carried out [above-mentioned] with the zero-order light by which reflection was carried out [above-mentioned] lead and interfere in an abbreviation same point, d) It is characterized by having the light sensing portion which measures the reinforcement of the above-mentioned interference light, and the spotting section which determines the location of the direction of an optical axis of each point of a device under test based on a change of the above-mentioned interference light measured by the light sensing portion on the strength, moving the e movable reflective section in the above-mentioned optical-axis direction.
[0015]
[Embodiment of the Invention] The solid configuration measuring device which has the above-mentioned structure measures a solid configuration by the following principles. First, light is irradiated from the light source at a device under test. In case this light is reflected in respect of [certain] the front face of a device under test (this point is hereafter called starting point), the high order diffracted light other than the direct reflected light (zero-order light) is generated. Among these, zero-order light is led to the movable reflective section (or radar clutter section) of a phase adjustable filter according to judgment optical system, and the high order diffracted light is led to the radar clutter section (or movable reflective section). Zero-order light and the high order diffracted light are led to one abbreviation according to an interference optical system, after being reflected in each part, respectively, both interfere there, and image formation of the image of the starting point of a device under test is carried out.

[0016] In such the condition, if the movable reflective section of a phase adjustable filter is moved within the limits of the wavelength of the light to be used, the phase of zero-order light (or high order diffracted light) reflected there will shift from the phase of the high order diffracted light (or zero-order light) reflected in the radar clutter section gradually. Therefore, the reinforcement of the interference light of both the light in the image formation point of an interference optical system also changes gradually. It depends on the location (it is the distance of a starting point and the movable reflective section correctly) of the starting point in a device under test for the location of the movable reflective section of the phase adjustable filter in the point (or some focus, such as a point used as min) that the reinforcement of this interference light serves as max. Therefore, the location of that starting point is computable from the location of the movable reflective section in this maximum point (or a certain focus) on the strength. The solid configuration of a device under test can be measured by performing such measurement and count about each point which constitutes the image of a device under test.
[0017] The solid configuration measuring device concerning this invention can also measure the spacial configuration of the interior about a transparent body to the light to be used besides appearance configuration measurement which was described above. Those applications are explained in detail in the following examples.
[0018]
[Example] Drawing 1 is the whole one example block diagram of the solid configuration measuring device concerning this invention. From the source 11 of the homogeneous light, it is projected on a certain linearly polarized light (for example, light of p-polarized light). The polarization illumination light on which it was projected from the source 11 of the homogeneous light passes the ring slit 12 for lighting, and turns into ring-like illumination light. This is called zona-orbicularis lighting. It is reflected by the polarization beam splitter 16 by the method of drawing Nakashita, and converges with a lens 15, and this zona-orbicularis illumination light passes the quadrant wavelength plate (lambda/4 plate) 14, and irradiates the phase body (device under test) 13. lambda/4 plate 14 changes the polarization condition of light, and, in the case of the example of this example, the linearly polarized light turns into the circular polarization of light.
[0019] In case the light irradiated by the phase body 13 is reflected on the front face, a phase changes according to the configuration (height of the direction of radiation) of the phase body 13. The reflected light which received the phase change passes lambda/4 plate 14 and a lens 15 again, and reaches a polarization beam splitter 16.
[0020] In the case of this example, the reflected light of a circular polarization of light condition becomes the time of an exposure, and reverse with s-polarized light by passing lambda/4 plate 14. Since a polarization beam splitter 16 reflects only p-polarized light, the reflected light which is s-polarized light passes through that. The reflected light also passes a polarization beam splitter 17 for the same reason, and the 2nd lambda/4 plate 18 prepared on it is passed. Under the present circumstances, s-polarized light turns into the circular polarization of light. This light passes the extinction filter 19 and reaches the phase adjustable filter 20.
[0021] Drawing 2 and drawing 4 explain the phase adjustable filter 20. The phase adjustable filter 20 has the configuration which laid underground the movable ring 202 with which the front face is a plane of reflection similarly on the substrate 201 with which the front face is a plane of reflection. As shown in drawing 4 in detail, the movable ring 202 moves up and down in the direction perpendicular to the front face of a substrate 201 with the drive 203 laid under the slot of the shape of a ring formed in the substrate 201. Besides, wavelength extent (when using the light, it is a maximum of about 800nm) of use light is enough as the magnitude of downward moving. A piezo-electric element can constitute a drive 203.
[0022] The magnitude (diameter) of the movable ring 202 is equivalent to the magnitude (diameter) of the above-mentioned ring slit 12 for lighting, and when it is reflected by the phase body 13, and the zona-orbicularis illumination light passes each above-mentioned optical element and results in the phase adjustable filter 20, it is set up so that the zero-order light may irradiate the movable ring 202 top exactly. Therefore, the high order diffracted light after primary irradiates the 201st page of the substrate

of the phase adjustable filter 20 among the reflected lights of the zona-orbicularis illumination light irradiated by the phase body 13.

[0023] The extinction filter 19 is arranged just before the phase adjustable filter 20, in the part (extinction section) 191 corresponding to the movable ring 202 of the phase adjustable filter 20, its permeability of light is low, and it is set up so that the maximum transparency of the light may be carried out in the other parts (area pellucida) 192, i.e., the part corresponding to a substrate 201. This is a thing which balances the quantity of light of both light to zero-order light since the quantity of light of a high order diffracted-light component is very small and to perform for accumulating. When not inserting such an extinction filter 19, it is because the effect of zero-order light becomes very large in the light sensing portion 22 mentioned later and change by the high order diffracted light is not reflected in an image formation image.

[0024] It is reflected on the front face of the phase adjustable filter 20, and the reflected light which passed the extinction filter 19 passes the extinction filter 19 again in a return trip, and passes lambda/4 plate 18. By passage of this lambda/4 plate 18, the reflected light which is the circular polarization of light turns into p-polarized light. Therefore, it is reflected in a polarization beam splitter 17, it converges with a lens 21, and the reflected light goes into a light sensing portion 22.

[0025] Next, an optical operation of this example which has such a configuration is explained. It shall consist of fields (crevice) 133 where only the depth [from the field (heights) 132 which projected only height h from datum level 131 and datum level for convenience as the front face of the phase body 13 was shown in drawing 3 , and datum level] d of explanation fell. In case the zona-orbicularis illumination light of the wavelength lambda irradiated by the phase body 13 is reflected in respect of these, only in thetah=(2.h/lambda) x2andpi, the phase is progressing as compared with the light in which the light reflected by heights 132 is reflected in datum level 131. In addition, an ambient atmosphere is atmospheric air and a refractive index is set to 1. On the other hand, as for the light reflected in a crevice 133, the phase is behind the light reflected in datum level 131 only in thetad=(2.d/lambda) x2andpi.

[0026] As aforementioned, zero-order light results in the movable ring 202 of the phase adjustable filter 20 among the light reflected by the phase body 13, and the high order diffracted light results in the 201st page of the substrate of the phase adjustable filter 20.

[0027] As shown in drawing 4 (a), when movable ring 202 front face has projected only distance a rather than substrate 201 front face, only phase thetaa (rad) progresses rather than the high order diffracted light in which the zero-order light reflected by movable ring 202 front face is reflected by substrate 201 front face.

thetaa=(2.a/lambda) x2andpi [0028] Although zero-order light is reflected by movable ring 202 front face among the light reflected by the heights 132 of the phase body 13 and the high order diffracted light is reflected by substrate 201 front face, respectively, both interfere and do image formation in a light sensing portion 22. therefore, the high order diffracted light to which only phase thetah progressed rather than the reflected light from datum level 131 as the brightness (light-receiving reinforcement) of heights 132 was shown in drawing 5 (a) among the images of the phase body 13 formed in a light sensing portion 22 -- and it becomes the vector sum with the zero-order light to which only phase thetaa progressed further. In addition, as above-mentioned, these magnitude of a vector (absolute value) is set up so that it may become equivalent extent according to an operation of the extinction filter 19. For convenience, in drawing 5 (and below-mentioned drawing 6), both the magnitude of a vector supposes that it is the same.

[0029] As shown in drawing 4 (b), when movable ring 202 front face becomes lower [distance b] than substrate 201 front face, as for zero-order light, a phase is behind [the high order diffracted light] only in thetab (rad).

thetab=(2.b/lambda) x2andpi [0030] in this case, the high order diffracted light to which only phase thetah progressed rather than the reflected light from datum level 131 as the brightness (light-receiving reinforcement) of heights 132 was shown in drawing 5 (b) like the above among the images of the phase body 13 formed in a light sensing portion 22 -- and it becomes the vector sum with the zero-order light in which only phase thetab was.

[0031] Therefore, if the reinforcement of the light (interference light of zero-order light and the high order diffracted light) received in a light sensing portion 22 is measured continuously, changing the location (distance from the 201st page of a substrate) of the movable ring 202 with a drive 203, it will change, as light-receiving reinforcement is shown in drawing 7 , and light-receiving reinforcement will serve as max in the location m of a certain movable ring 202. This condition corresponds, when the vector of zero-order light and the vector of the high order diffracted light turn to the same direction, as shown in drawing 5 (c). Therefore, the maximum point on the strength can be detected from the graph (graph of drawing 7) of a measured change on the strength, and height h of the heights 132 of the phase body 13 can be computed like [m / of the zero-order light in the point / phase change theta] a degree type.
H=lambda-thetam/(4andpi) [0032] Similarly, zero-order light is reflected on movable ring 202 front face, the high order diffracted light is reflected on substrate 201 front face, respectively, and the interference light of both light carries out image formation also of the light reflected in the crevice 133 (depth b) of the phase body 13 in the part of the crevice 133 of the image of the phase body 13 in a light sensing portion 22. Among these, the high order diffracted light is behind datum level 131 only in phase thetab, and according to the location of the movable ring 202, the phase of zero-order light changes, as shown in drawing 6 (a), (b), and (c). Therefore, depth b of a crevice 133 is computable as follows from phase change thetam of the zero-order light in the highest reinforcement. B=lambda-thetam/(4andpi)
[0033] In a light sensing portion 22, equipment like a CCD camera which can acquire data two-dimensional is used. By detecting such light-receiving reinforcement in each point of the image of the phase body 13 formed in a light sensing portion 22, moving the movable ring 202 of the phase adjustable filter 20 Finally the height (depth) in each point of the phase body 13 can be measured, and the solid configuration of the phase body 13 can be measured.
[0034] Although the movable ring 202 of the ring slit 12 for lighting, the extinction filter 19, and the phase adjustable filter 20 must be the same configuration, the concrete form can also be made square annular, as it is not restricted in the shape of [above] a circular ring, for example, is shown in drawing 8 . Moreover, it is not necessary to necessarily suppose that it is annular, and as shown in drawing 9 (a) or (b), you may prepare only in the center. For example, when it is very small a diameter [like laser] of a spot whose light source is, it is hard to create zona-orbicularis lighting. In such a case, spot-like an extinction filter and a phase adjustable filter as shown in drawing 9 (a) or (b) are used. In addition, as shown in drawing 10 , in order that light source 31 self may project spot-like light in this case, the slit for lighting is unnecessary.
[0035] Although the above-mentioned example explained as a solid configuration measuring device which is made to reflect the projected light on the front face of a phase body, and measures the solid configuration, this invention can be used also as transparency mold equipment which detects similarly the light which penetrated the phase body (device under test). In this case, a internal structure besides the solid configuration of the appearance of that phase body can also be detected now in three dimensions. That is, if there is a part on which use light (the light, infrared radiation, ultraviolet rays) is scattered by the difference in physical properties in the interior of a body, since the high order diffracted light other than zero-order light will be emitted from the part, the location of the height (depth) direction is detectable with the above-mentioned principle. The example of a configuration of such transparency mold equipment is shown in drawing 11 . In this example, since it is in the location where the optical projection system and a transmitted light analysis system face on both sides of the phase body 13 unlike the example of drawing 1 , in the optical projection system, the light source 41, the ring slit 42 for lighting, and only the lens 43 are required, and the polarization beam splitter 16 for dividing incident light and the reflected light and lambda/4 plate 14 are unnecessary. The configuration of a transmitted light analysis system is the same as that of the thing of drawing 1 .
[0036] Moreover, the example of a configuration of the transparency mold measuring device using spot-like incident light is shown in drawing 12 .
[0037] In this invention, the migration precision of the moving part of a phase adjustable filter has big **** on the accuracy of measurement. Therefore, when performing highly precise configuration

measurement, it is desirable to use together a means to measure the movement magnitude of the moving part of a phase adjustable filter. The example which added a means to measure the movement magnitude of the movable ring 202 of the phase adjustable filter 20 to the solid configuration measuring device of drawing 1 to drawing 13 is shown. From the light source 81, it is projected on the light of a specific polarization condition (for example, s-polarized light). This light is carried out with a half mirror 82 for 2 minutes, one side passes a half mirror 82, and goes straight on, and the light of another side results in the reflecting mirror 84 of the method of drawing Nakagami. It is reflected by the polarization beam splitter 83 by the method of drawing Nakagami, and the light which passed the half mirror 82 results in the phase adjustable filter 20. This light receives a phase change according to that location, in case it is reflected in the movable ring 202 of the phase adjustable filter 20. It is again reflected by the polarization beam splitter 83, and the light by which the phase change was carried out results in a half mirror 82. On the other hand, it is reflected by the upside reflecting mirror 84 and the light reflected up by the half mirror 82 returns to a half mirror 82. Since it is fixed, the phase of the light which returns by the root here of the upside reflecting mirror 84 is always fixed. Therefore, as for the light of the both sides which joined in the half mirror 82, the interference reinforcement changes according to the location (height and depth) of the movable ring 202 of the phase adjustable filter 20.

[0038] It is reflected by the method of drawing Nakashita, it converges with a lens 85, and image formation of the interference light which joined by the half mirror 82 is carried out by the light sensing portion 86. By observing change of this interference light reinforcement, it becomes possible to measure the movement magnitude of the movable ring 202 of the phase adjustable filter 20. In addition, this applies the Michelson interferometer generally known.

[0039]

[Effect of the Invention] Since the solid configuration measuring device concerning this invention is a thing using interference of light, it can measure the configuration of a device under test to nano meter order. And a probe is not scanned mechanically but a device under test is photoed at once optically, and since a solid configuration can be measured only by detecting the reinforcement of each point which constitutes the image, while being able to measure a solid configuration in the big range, as compared with the case where it scans mechanically, it can measure extremely in a short time. Moreover, since it measures by non-contact, while a very soft object can also measure, good measurement of repeatability with high objectivity can be performed, without being influenced by the hardness (rigidity) of a device under test.

[0040] Furthermore, by using the equipment of the transparency mold concerning this invention, it is possible to measure the internal structure of a cell in three dimensions etc., and large application can be considered also to biotechnology-related precise measurement.

[Translation done.]

DESCRIPTION OF DRAWINGS

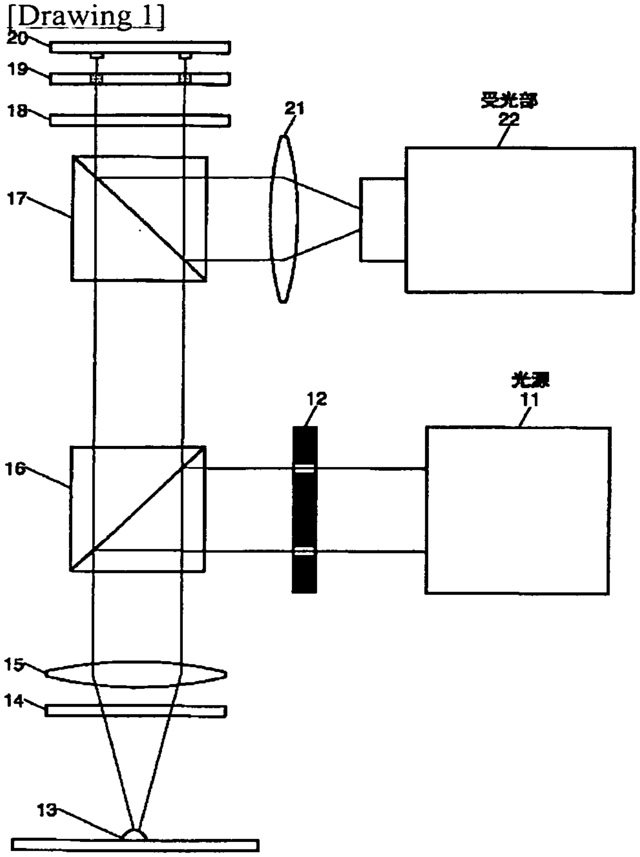
[Brief Description of the Drawings]
[Drawing 1] The system configuration Fig. of the reflective mold solid configuration measuring device which is the 1st example of this invention.
[Drawing 2] The perspective view of the extinction filter used in the 1st example, and a phase adjustable filter.
[Drawing 3] The mimetic diagram showing the example of a configuration of a phase body (specimen) front face.
[Drawing 4] The mimetic diagram showing the situation of reflection of the zero-order light in a phase adjustable filter, and the high order diffracted light.
[Drawing 5] The vector diagram showing the phase relation between zero-order light, the high order diffracted light, and its unification light.
[Drawing 6] The vector diagram showing the phase relation between zero-order light, the high order diffracted light, and its unification light similarly.
[Drawing 7] The graph which shows unification luminous-intensity change detected by the light sensing portion when the moving part of a phase adjustable filter is moved.
[Drawing 8] The perspective view showing the example of other configurations of the slit for lighting, an extinction filter, and a phase adjustable filter.
[Drawing 9] The perspective view showing the example of a spot-like extinction filter and a phase adjustable filter.
[Drawing 10] The system configuration Fig. of the example in the case of using spot-like incident light.
[Drawing 11] The system configuration Fig. of the example of a transparency mold measuring device.
[Drawing 12] The system configuration Fig. of the example of the transparency mold measuring device using spot-like incident light.
[Drawing 13] The system configuration Fig. of an example in which the auxiliary device for measuring the location of the moving part of a phase adjustable filter correctly was formed.
11, 31, 41, 81 -- Light source
12 42 -- Ring slit for lighting
13 -- Phase body (device under test)
131 -- Datum level
132 -- Heights
133 -- Crevice
14 18 -- lambda/4 plate
15, 21, 43, 85 -- Lens
16, 17, 83 -- Polarization beam splitter
19 -- Extinction filter
20 -- Phase adjustable filter
201 -- Substrate
202 -- Movable ring

203 -- Drive
22 86 -- Light sensing portion
82 -- Half mirror
84 -- Reflecting mirror

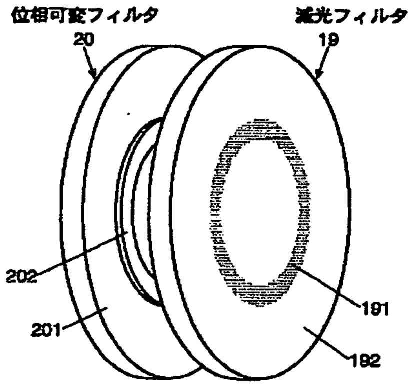
[Translation done.]

DRAWINGS

[Drawing 1]



[Drawing 2]



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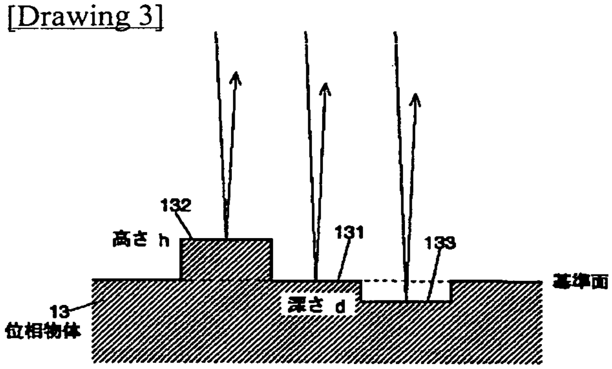
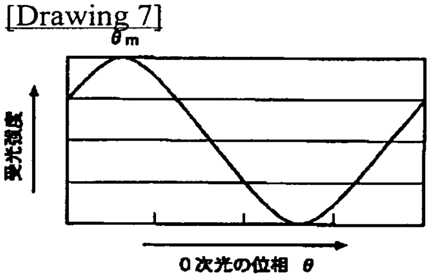
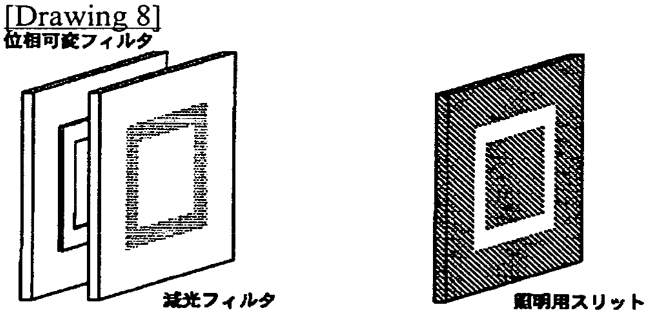


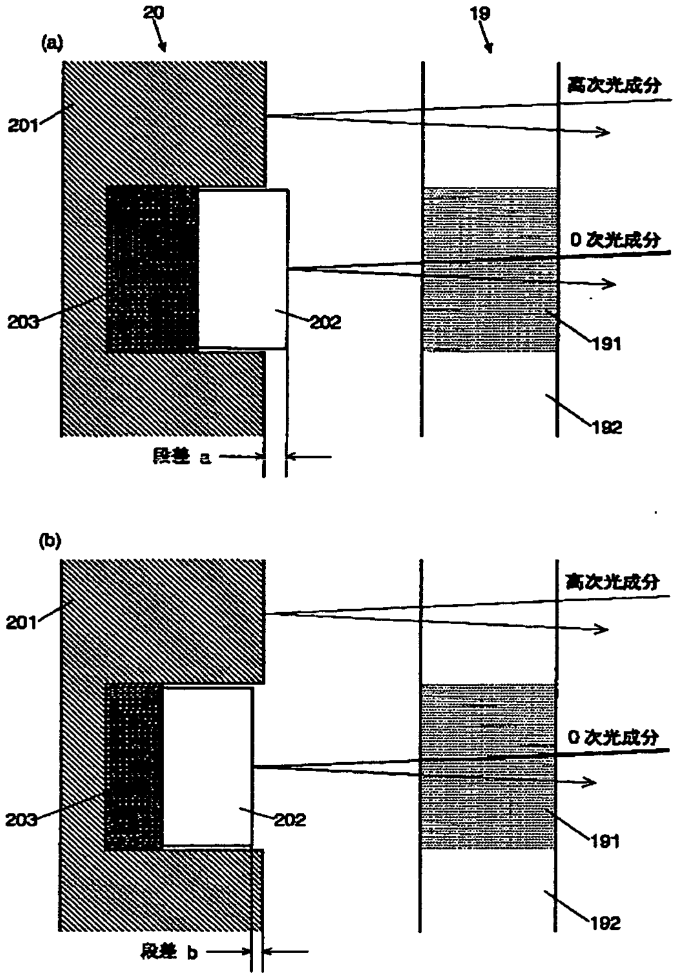
[Drawing 7]



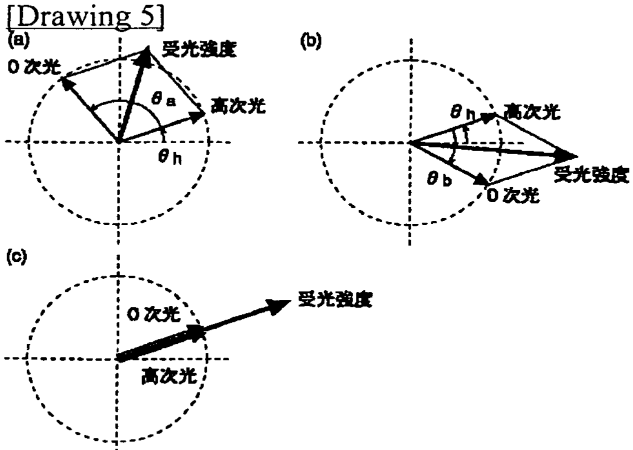
[Drawing 8]



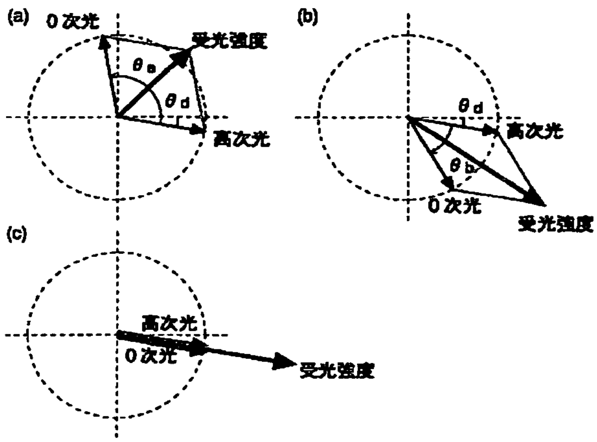
[Drawing 4]



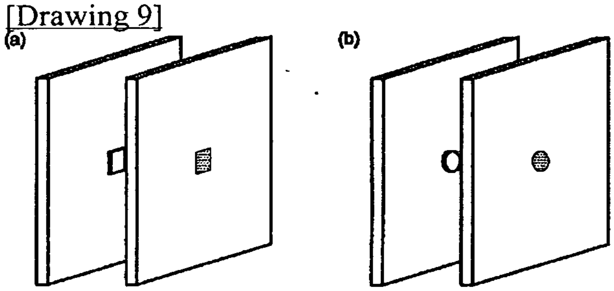
[Drawing 5]



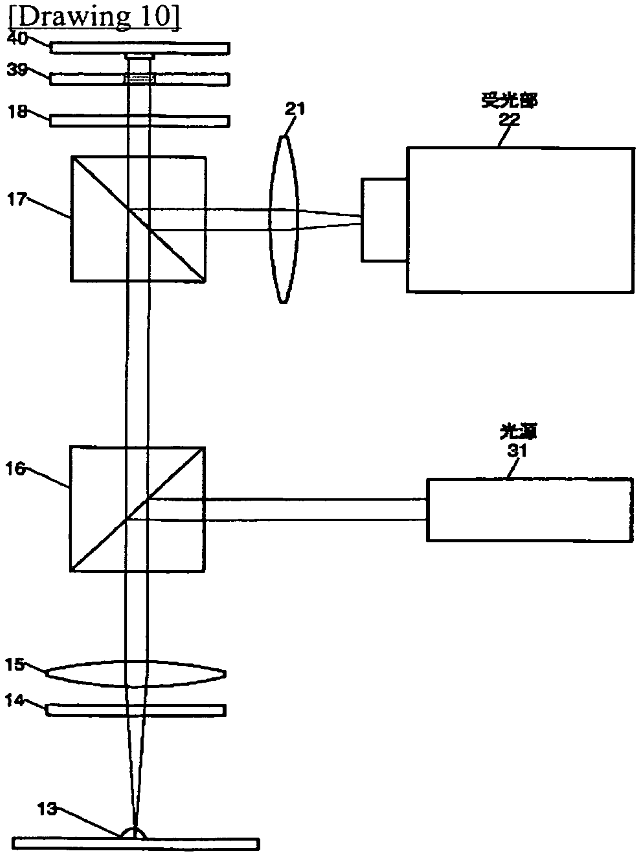
[Drawing 6]



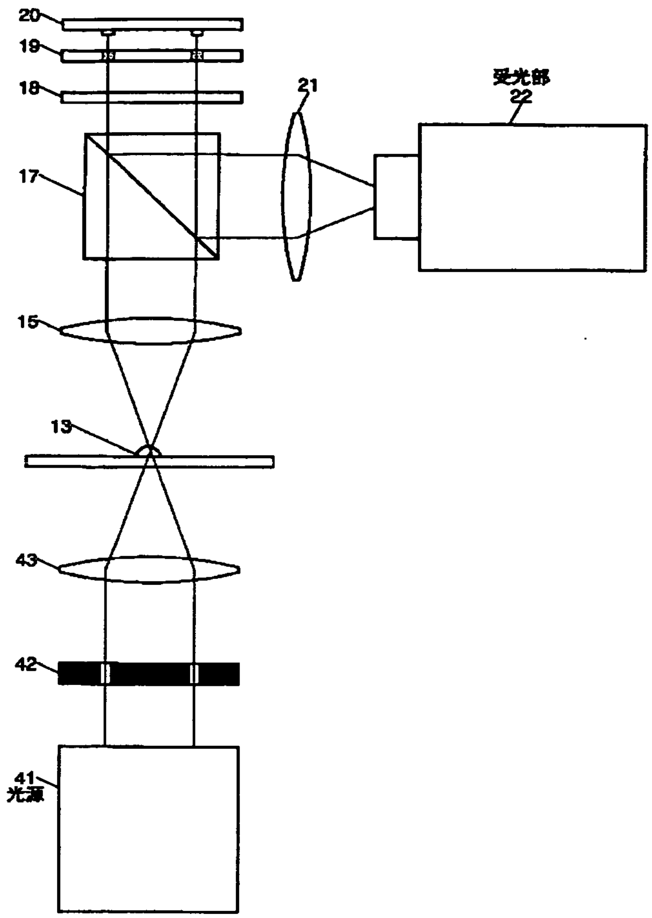
[Drawing 9]



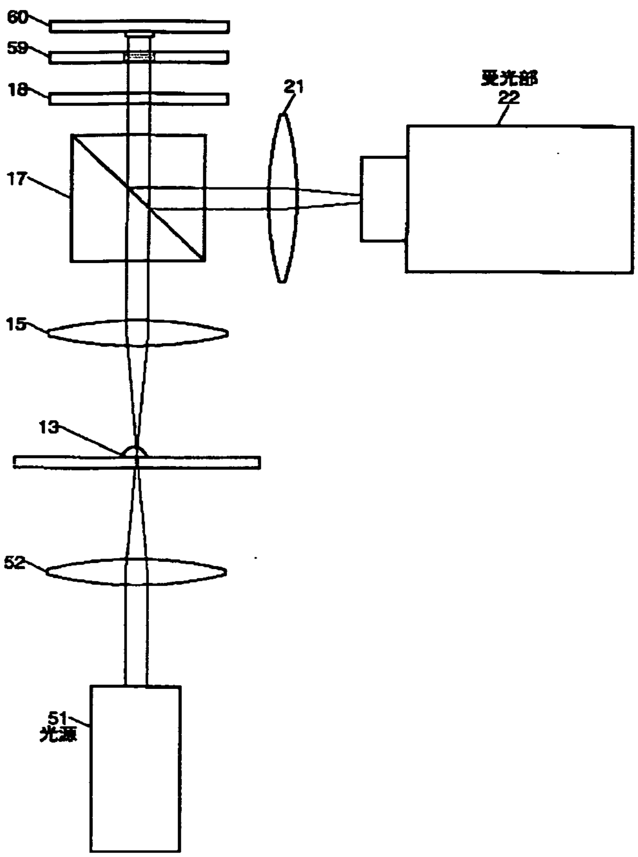
[Drawing 10]



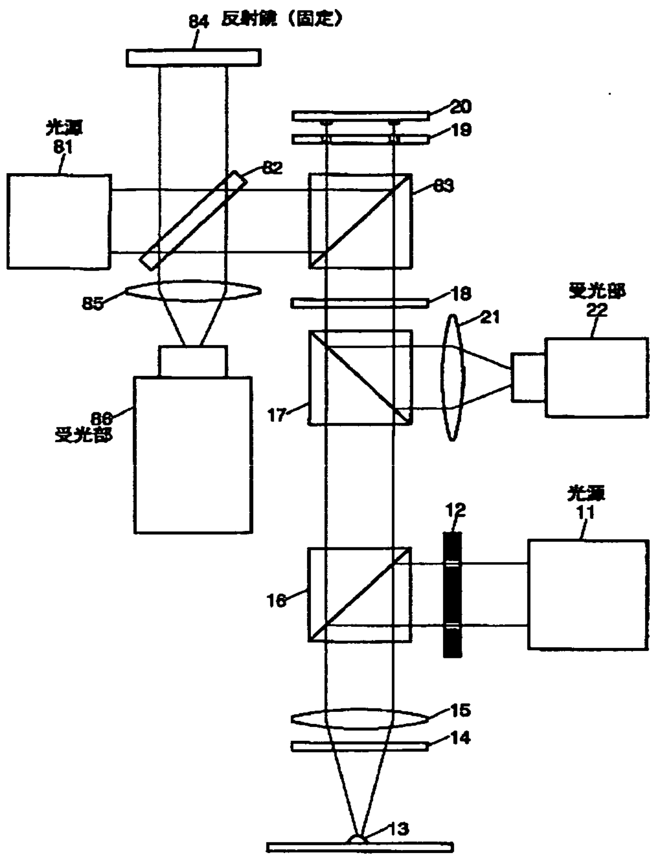
[Drawing 11]



[Drawing 12]



[Drawing 13]



[Translation done.]